§4. Effect of Additional Neutral Beam Heating on High Ion Temperature Mode in CHS

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Additional heating of ctr-injected neutral beam was applied to the co-based High-Ti mode[1] plasma. The ion temperatures, measured by NPA, tend to reach its maximum 10-ms after the injection of ctr-NB and saturate at certain temperature. To see the optimum condition of injection for ctr-NB, the injection timing was scanned.

In analyzing these discharges, the ion heating rate (P_i) and electron heating rate (P_e) of bulk plasma by beam ions at the center were examined using the following formulae;

$$P_i = \int_0^\tau \sum_j \left(n_{b0,j} f_{i,j} (dE_b/dt)_j \exp(-t/\tau_c) \right) dt \quad (1), \text{ and}$$

$$P_e = \int_0^\tau \sum_j \left(n_{b0,j} f_{e,j} (dE_b/dt)_j \exp(-t/\tau_c) \right) dt \quad (2).$$

where f_i and f_e are the heating fraction of ions and electrons[2]. τ is the slowing down time of beam ions, $\tau=(\tau_{se}/3)ln(1+(E_{b0}/E_c)^{3/2})$[3]. The loss of fast ions was taken into account by τ_c with exponential function. The j denotes the beam component (j =1,2,3).

The calculated single ion heating rate by beam ions are shown by contours in Fig.1 for given central electron density and temperature by assuming the same beam deposition as the co-NB only discharge. The beam confinement time(τ_c) of 20 ms is adopted in the calculation. The effect of τ_c significantly appears in the upper left region of the figure, since τ_c becomes comparable to or larger than τ_{se} in that region. If the longer τ_c is applied, the heating rate of a single ion will increase, especially at the upper left corner of the figure.

The time trace of the co-NB only discharge is plotted by lines with open circles in Fig.1. The energy input to single ion ($P_i(0)/n_i(0)$) increases during t = 30-60 ms. After 60 ms, the energy input is gradually changing with time, and reaches its maximum at t = 90 ms. This tendency resembles to that of ion temperature measured by NPA. In Fig. 2, $P_i(0)/n_i(0)$ at each point is plotted against T_iNPA together with those of co/ctr-NB injection discharges. To avoid the change in plasma characteristics after ctr-NBI, the time of interest was limited to the first 10 ms of ctr-NB injection. Between T_iNPA and $P_i(0)/n_i(0)$, strong correlation is found. The ion temperature of the discharge seems to be dominated by the energy input to a single ion by fast ions. In Fig. 2, there is one point which strongly deviates from the line of the correlation. Further analysis is necessary for this case.

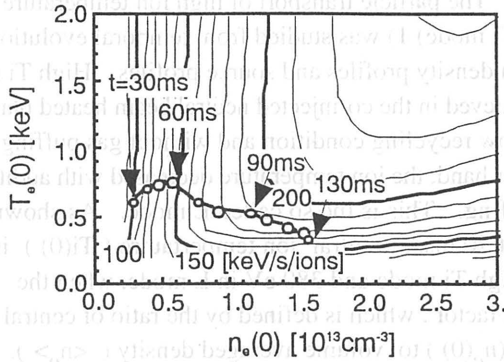

Fig. 1. Calculated heating rate of a single bulk ion by beam ions for the co-NB only discharge. The time trace of ($n_e(0)$,$T_e(0)$) is plotted by lines with open circles.

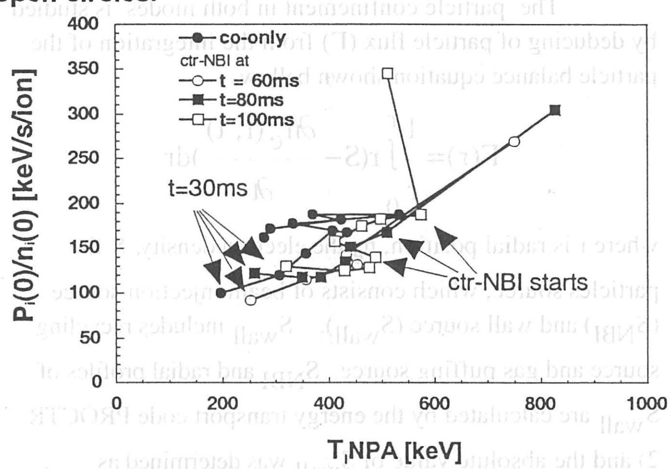

Fig.2 Correlation between heating power to a single bulk ion(P_{i0}/n_{i0}) and ion temperature obtained by NPA(TiNPA). The line with open circles, closed circles, open squares, and closed squares show the case of co-NB injected discharge, co/ctr-NB injected(ctr-NB at t=60ms), co/ctr-NB injected(ctr-NB at t=80ms), and co/ctr-NB injected (ctr-NB at t=100ms), respectively. The dashed line shows the correlation curve between P_{i0}/n_{i0} and TiNPA.

References

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